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THE BY-PRODUCTS OF RICE MILLING.[1]

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INTRODUCTION.

Most of the rice produced in the United States is grown and milled in the States of Louisiana, Texas, Arkansas, and California. A few mills also are under operation in North Carolina, South Carolina, and Georgia. Although the processes employed in rice milling are old in principle, a marked improvement has taken place in the industry during the past decade. As the industry is carried on in such a limited area of the country, however, these processes are probably unfamiliar to many people who do not live in the rice-growing sections. A description of the rice grain as it comes to the mills and of the essential steps in rice milling seems, therefore, a desirable preliminary to a discussion of rice by-products.

The three varieties of rice commonly grown in the Louisiana, Texas, and Arkansas rice districts are: Japan, Honduras, and Blue Rose. The Japan type has a short, thick grain, the Honduras type has a long kernel, while the Blue Rose type is intermediate between these two in size. The Blue Rose type, although of comparatively recent introduction, has increased rapidly in popularity because of its productiveness and milling qualities.

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[1] This bulletin gives the results of an investigation of the rice-milling industry, conducted with special reference to the by-products obtained in the milling of rice. It should be of interest to rice millers, feed-control officials, feed manufacturers dealers, and feeders of stock.

[2] Acknowledgment is made to F. B. Wise, of the Bureau of Plant Industry, and A. W. Broomell, formerly of the Bureau of Chemistry, for the use of descriptive matter from U. S. Dept. Agr. Bul. 330, and to P. B. Yost and F. L. Elliot, of the New Orleans Laboratory of the Bureau of Chemistry, for assistance in the analytical work.

The rice grain as it is received at the mill from the farm thrasher is contained in a hard, siliceous hull which incloses the edible kernel. This hull is covered with small needlelike points very high in silica content. Directly beneath the hull, but separate from it and attached firmly to the endosperm or starchy body of the kernel itself, is a light-brown bran coat. The microscope reveals seven distinct layers of bran. At one end of the hulled kernel the germ or embryo is distinctly visible. The milling process normally removes the germ, six of the bran layers and a part of the seventh or aleurone layer, and leaves only the starchy part of the kernel surrounded by a portion of the last layer. The aleurone cells are very rich in protein and only about 10 per cent of the protein of the hulled rice is removed by milling. Most of the oil, however, is contained in the germ, and since all of the germ goes into the bran about 85 per cent of the oil content of the kernel is removed.

DESCRIPTION OF THE MILLING PROCESS.

The rice as it comes to the mill is termed "rough rice" and usually is received in sacks which ordinarily contain from 175 to 210 pounds each, the average being about 190 pounds. The trade, however, usually considers that 162 pounds constitute a "barrel." From the mill warehouse the rough rice is elevated to the top floor of the mill, where the cleaning process begins. The rough rice goes over a machine called a "scalper," which removes the sticks, stones, and other coarse material by screens and removes the dust and fine material by suction. From the scalper the rice goes to the "clipper," which removes the long beard and stems; and from the clipper to a "monitor," which by suction removes light or blighted grains of rice. The product now might be termed "cleaned rough rice," and upon this product the milling process proper is conducted.

MILLING MACHINERY.

Hulling stones.—The milling process may be divided into three parts, each of which removes a different portion of the rice and produces a distinct by-product. The first step is the removal of the hull; the second, the removal of the outer bran; and the third, the removal of the inner bran. The cleaned rough rice goes to a pair of milling stones, similar to the old-time flour-mill buhrstones. These stones, the top one of which usually revolves, are set some distance apart, so that the revolving of the stone causes the grains to assume a somewhat vertical position. In this position a pressure is exerted on the ends of the grain, which cracks or splits the hull, allowing the kernel to drop out. Care is taken to set the stones a sufficient distance apart so that there will be as little breaking of the kernel as possible, as broken rice sells for less and is graded lower than whole rice. It is worth noting that the breaking by the stones usually is lengthwise rather than transverse. Many of the transverse breaks are already in the rice when it arrives at the mill.

Stone reel.—From the stones the mixture of hulled rice, unhulled rice, and hulls goes to the so-called "stone reel." This reel is a large revolving, octagonal framework covered with wire screens, the square meshes of which are usually 14 to the linear inch. Both finer and coarser meshes are sometimes used. The fine material passing through this screen consists of broken hulls, germs, and true bran. It is termed "stone-reel bran." The rice and hulls passing over the stone reel are conducted to a monitor which removes the loose hulls by suction.

Paddy machine.—The rice stream goes to the "paddy machine," a device for separating the rough from the hulled rice. This machine consists of a large, mechanically-operated box shaker with zigzag divisions formed by vertical metallic plates. These plates, together with the shaking, aid gravity in making a separation of the lighter, unhulled grains from the heavier, hulled grains. The rough-rice grains gradually move upward from the center feed and pass over the machine into a trough, while the heavier, hulled grains are collected under the lower side. The unhulled or "paddy" grains go to a pair of auxiliary stones similar to the first stones, but set somewhat closer together. The stream from these stones reenters the main stream going to the stone reel.

Hullers.—The natural brown rice from the clean-rice side of the paddy machine is conducted to a set of so-called "first-break hullers." The name "huller" applied to these machines is misleading, as their purpose is to remove the bran layers from the grain which already has been hulled. The huller consists of a grooved, tapering cylinder revolving within a concentric hollow cylinder so spaced as to rub loose a portion of the bran coat with as little breaking of the grain as possible. In outward appearance it resembles a large sausage machine.

After leaving the first set of hullers the loosened bran is separated in its passage through the first-break reel and constitutes the first-break bran. The rice goes to a second set of hullers similar to the first set, but adjusted to bring the parts more closely together, so as to remove a further portion of the bran coat. Again the stream passes through a reel which separates out the second-break bran.

Pearling cone.—In some mills the bran is removed more gradually and some millers believe that the breakage is reduced by the use of a machine known as a "pearling cone." This machine consists of a frustum of a cone covered with a composition stone which is surrounded by a sieve mantel of heavy iron wire. The rice is fed from the top and is rubbed thoroughly between the cone and the sieve before passing out at the bottom. The severity of the scouring may be varied by raising or lowering the cone, thus decreasing or increasing its distance from the wire screen. One or two of these pearling cones are used in addition to one or two sets of hullers. The product taken off by the pearling cone is generally known as "pearling-cone meal" and may be sold as such, although some mills make a practice of mixing this product either with their bran or polish, as demand or price may dictate.

Brush.—During the milling in the hullers and pearling cone the rice becomes very warm, and, hence, before further treatment it is run to large cooling bins where it is allowed to remain for several hours. A further reason for collecting the grain in bins at this point lies in the fact that a uniform flow of rice to the brush is necessary for good milling, and the brush handles rice much more rapidly than the hullers or pearling cone. It is therefore necessary to store the rice from the hullers and pearling cone until such an amount has been partly milled that a uniform feed for the brush machine is assured before it is started. From these bins the rice, which is now practically white in color, but is more or less rough and unsightly in appearance, is conveyed to the brush to remove more of the inner bran coat and to give the rice a smoother finish.

The brush consists of a vertical cylindrical frame covered with a thick padding of soft leather strips. This frame revolves at a high rate of speed within a cylinder of wire screen. The rice enters at the top of the brush and is rubbed smooth by friction with the brush and screen while passing to the bottom of the machine. A considerable amount of heat develops in the brush, and it is found necessary to cool the brush by passing a stream of air upward through it. This air current carries with it a small amount of polish which is recovered in dust collectors. The material which passes through the screen of the brush, mixed with the small amount of material from the dust collectors, constitutes the rice polish usually found on the market. The rice leaving the brush machine is suitable for market, although, as a rule, it is separated into different grades by a system of screens or graders, and in many cases is given a high finish by the use of a small amount of glucose and talc.

A graphic diagram of the mill process is shown in figure 1.

ANALYSIS OF RICE AND ITS BY-PRODUCTS.

With a few minor variations the process just described is followed in all rice mills. It results in three by-products, namely, rice hulls; a rice bran, consisting of a mixture of the stone-reel, first-huller, and second-huller brans; and rice polish.

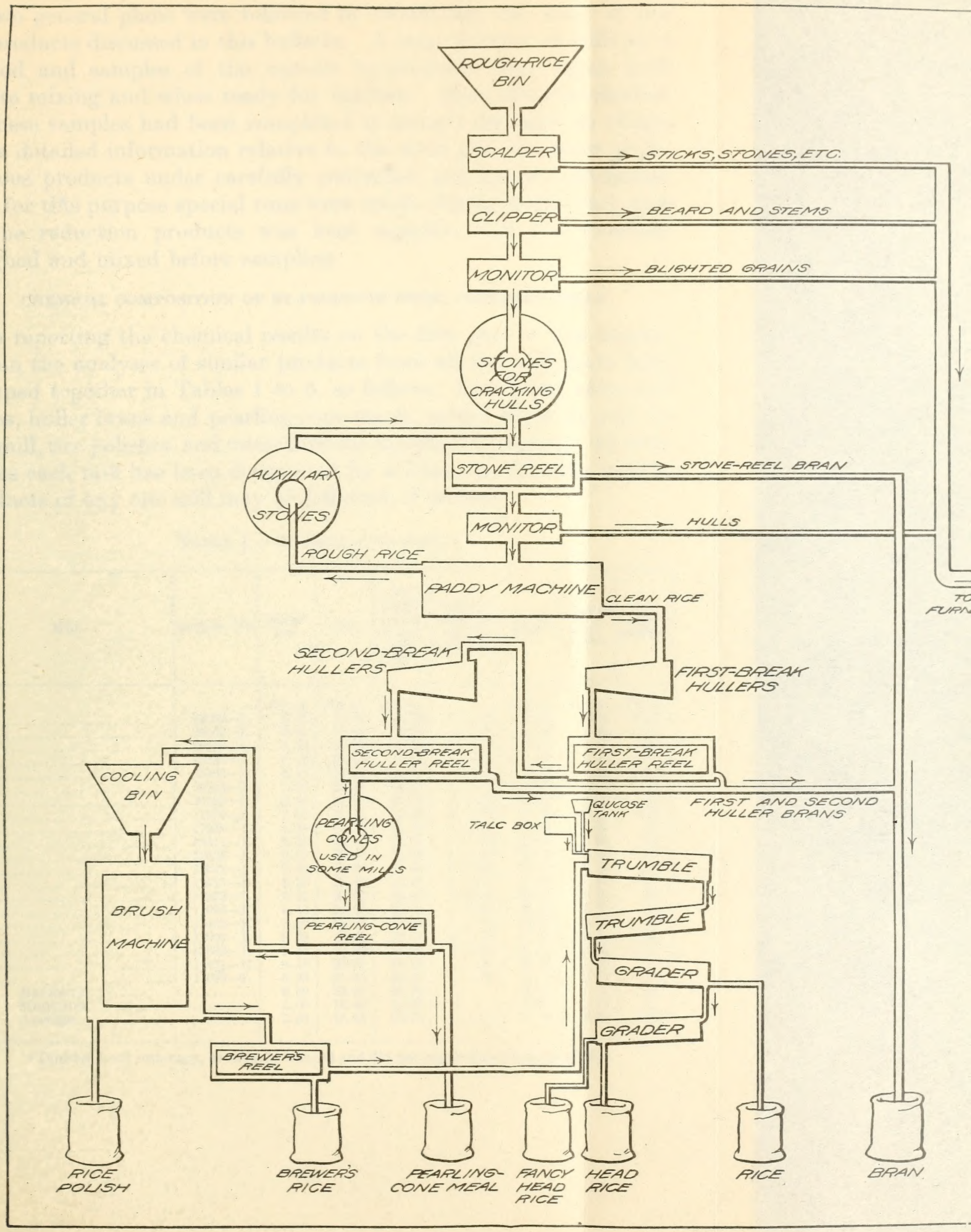

FIG. 1.—Graphic diagram of a typical rice mill.

Two general plans were followed in conducting the study of rice by-products discussed in this bulletin. A large number of mills were visited and samples of the various by-products were taken both before mixing and when ready for market. After the examination of these samples had been completed it seemed desirable to obtain more detailed information relative to the yield and character of the various products under carefully controlled and known conditions, and for this purpose special runs were made, during which each part of the reduction products was kept separate and was carefully weighed and mixed before sampling.

CHEMICAL COMPOSITION OF BY-PRODUCTS FROM DIFFERENT MILLS.

In reporting the chemical results on the first part of this investigation the analyses of similar products from all the mills have been grouped together in Tables 1 to 6, as follows: Rice hulls, stone-reel brans, huller brans and pearling-cone meals, mixed brans as sold by the mill, rice polishes, and miscellaneous samples of interest. In these tables each mill has been designated by a letter, so that the various products of any one mill may be followed, if desired.

TABLE 1.—*Analyses of rice hulls.*

Mill.	Sample No.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.	Protein (N× 6.25).	Ether extract.
		Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
A	25062—L	5.47.	18.80	17.72	1 : 1.07	46.82	2.81	0.64
B	25067—L	6.91	19.12	18.22	1 : 1.05	44.70	2.50	1.15
C	25078—L	5.00	18.04	16.78	1 : 1.08	36.57	4.12	.68
D	25090—L	7.19	17.31	16.11	1 : 1.07	46.48	3.16	1.10
E	25160—L	8.20	20.01	18.84	1 : 1.06	40.95	3.49	1.22
F	25165—L	7.76	21.43	20.67	1 : 1.04	40.96	2.37	.31
G	25192—L	6.44	21.48	20.66	1 : 1.04	41.16	2.02	.36
I	[1] 11976—L	7.66	21.13	20.24	1 : 1.04	40.46	3.68	4.77
J	17059—L	8.85	17.40	16.70	1 : 1.03	42.50	2.20	.77
K	15311—K	9.25	20.59	19.67	1 : 1.04	39.23	2.94	.83
L	12655—L	9.37	22.03	20.98	1 : 1.05	38.95	1.88	.73
M	12643—L	7.88	20.63	19.88	1 : 1.03	43.01	2.56	.67
N	12613—L	8.28	16.40	15.27	1 : 1.07	44.29	3.14	1.31
O	12622—L	6.31	20.79	19.97	1 : 1.04	39.84	1.75	.53
P	11978—K	8.45	20.06	19.35	1 : 1.03	42.94	2.73	.53
Q	15435—K	7.97	18.14	17.17	1 : 1.06	38.62	2.85	.82
R	12604—L	9.69	17.24	16.14	1 : 1.06	41.65	2.64	1.04
S	12632—L	9.43	19.69	18.90	1 : 1.04	39.90	2.69	1.17
T	15451—K	9.38	20.81	19.90	1 : 1.05	39.39	2.08	.51
U	17086—L	8.93	21.35	20.10	1 : 1.06	36.57	2.52	.86
Maximum		9.69	22.03	20.98		46.82	4.12	1.31
Minimum		5.00	16.40	15.27		36.57	1.75	.51
Average		7.93	19.54	18.58	1 : 1.05	41.29	2.66	.80

[1] Omitted from summary, as the mill was old and did not make separations properly.

TABLE 2.—*Analyses of stone-reel brans.*

Mill.	Sample No.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.	Protein (N× 6.25).	Ether extract.
		Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
A	25053—L	9.31	15.96	12.16	1 : 1.27	20.40	10.69	8.15
B	25068—L	9.96	16.17	13.10	1 : 1.23	22.63	7.69	7.30
C	25080—L	6.75	17.61	14.24	1 : 1.24	23.50	9.81	7.38
D	25089—L	9.26	12.24	9.12	1 : 1.34	19.14	11.69	9.09
E	25157—L	9.93	13.42	9.44	1 : 1.42	15.83	12.44	11.08
F	25163—L	10.69	15.47	11.47	1 : 1.34	18.84	10.31	7.21
G	25183—L	10.25	14.58	11.61	1 : 1.28	22.01	9.22	6.06
I	11975—L	10.37	12.35	8.37	1 : 1.47	16.15	11.20	10.00
J	17061—L	10.43	13.50	9.70	1 : 1.39	18.26	10.01	10.04
K	15312—K	9.34	14.53	10.31	1 : 1.41	23.35	11.64	8.38
L	12654—L	10.40	16.06	12.84	1 : 1.25	18.06	9.41	6.56
M	12644—L	9.80	16.91	13.53	1 : 1.25	22.20	10.00	8.73
N	12612—L	8.07	14.05	10.15	1 : 1.38	17.19	10.89	9.48
O	12621—L	7.03	19.29	16.07	1 : 1.20	24.62	7.49	6.59
P	11989—K	8.86	13.22	7.74	1 ; 1.70	9.40	11.19	9.15
Q	15441—K	9.52	14.98	12.18	1 : 1.20	26.49	8.48	5.15
R	12603—L	17.31	10.80	6.85	1 : 1.56	14.35	11.00	7.98
S	[1] 12631—L	10.45	14.74	12.14	1 : 1.21	18.42	9.78	6.65
S	[1] 12664—L	8.20	18.98	16.85	1 : 1.13	25.05	8.07	5.78
T	[2] 15453—K	10.95	4.69	1.21	1 : 3.88	5.63	14.53	9.59
U	17088—L	14.26	17.67	12.82	1 : 1.37	15.72	10.56	9.47
V	11957—L	14.37	11.60	6.19	1 : 1.87	15.35	12.86	13.54
Maximum		17.31	19.29	16.85		26.49	12.86	13.54
Minimum		6.75	10.80	6.19		9.40	7.49	5.15
Average		10.19	14.97	11.28	1 : 1.33	19.38	10.21	8.28

[1] Samples were taken from different runs of the same mill at intervals of approximately two months.

[2] Omitted from summary, as the figures reported on this sample are very abnormal, due to the remilling of broken rice.

TABLE 3.—*Analyses of huller brans and pearling-cone meals.*

Mill.	Sample No.	Type of rice and by-product.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.	Protein (N× 6.25).	Ether extract.
		BLUE ROSE:	*P. ct.*	*P. ct.*	*P. ct.*		*P. ct.*	*P. ct.*	*P. ct.*
A	25056—L	First-break huller bran	9.72	7.44	0.58	1:12.82	8.42	16.69	20.00
B	25069—L	Do	8.38	8.25	1.24	1: 6.65	8.37	15.81	19.35
E	25158—L	Do.[1]	7.98	7.64	.90	1: 8.50	8.37	15.94	20.12
K	15313—K	Do	9.56	9.34	.61	1:15.31	7.32	16.85	18.89
M	12645—L	Do	10.28	8.67	1.88	1: 4.61	9.36	14.35	18.91
S	12665—L	Do	9.32	7.65	2.99	1: 2.56	9.34	13.68	15.77
E	25155—L	Second-break huller bran[1]	8.03	8.18	1.15	1: 7.12	7.61	15.06	16.21
K	15314—K	Do	8.78	8.96	.87	1:10.30	8.31	18.64	20.61
M	12646—L	Do	10.00	8.75	1.28	1: 6.83	7.85	14.88	18.21
S	12666—L	Do	10.38	6.48	3.01	1: 2.15	6.92	11.37	10.23
C	25081—L	Mixture of first- and second-break huller brans[2]	8.97	5.00	.40	1:12.50	4.13	12.00	10.97
D	25091—L	Do	7.62	7.07	1.17	1: 6.05	7.79	15.38	17.56
J	17079—L	Do	10.76	7.20	1.00	1: 7.20	8.66	15.33	17.94
O	12623—L	Do	7.48	10.38	2.63	1: 3.95	10.13	14.11	20.09
R	12605—L	Do.[3]	13.28	4.70	.53	1: 8.86	5.19	11.37	10.44
R	12606—L	Do.[3]	9.96	4.63	.49	1: 9.43	2.28	10.71	10.78
U	17087—L	Do	10.54	8.89	1.88	1: 4.72	8.97	16.09	19.96
A	25059—L	Pearling-cone meal	6.87	8.20	1.04	1: 7.90	8.54	17.06	19.42
B	25074—L	Do	9.68	7.84	.72	1:10.90	3.95	15.00	16.20
D	25097—L	Do	8.93	7.56	.80	1: 9.16	5.83	14.56	18.55
J	17071—L	Pearling-cone meal (1st)	8.99	8.57	.55	1:15.58	6.10	14.98	16.38
J	17073—L	Pearling-cone meal (2d)	9.28	7.55	.54	1:14.00	3.26	14.06	16.98
J	17075—L	Pearling-cone meal (3d)	9.31	6.27	.55	1:11.40	1.41	13.14	13.61
		HONDURAS:							
G	25189—L	First-break huller bran	8.87	8.44	1.10	1: 7.67	7.87	15.25	17.64
H	25101—L	Do	8.80	8.17	1.00	1: 8.17	7.39	15.88	18.33
I	11981—L	Do	10.53	9.52	1.59	1: 5.98	7.72	13.97	17.21
L	12657—L	Do	10.58	7.98	.82	1: 9.73	6.92	14.48	17.02
Q	15442—K	Do	8.97	7.60	.61	1:12.50	8.28	17.67	18.58
G	25190—L	Second-break huller bran	7.44	9.72	1.01	1: 9.63	7.41	14.28	17.27
H	25198—L	Do	9.77	9.75	.51	1: 1.95	8.98	14.56	18.94
I	11983—L	Do	11.05	10.09	2.11	1: 4.78	9.72	12.40	13.92
L	12658—L	Do	10.87	9.76	.63	1:15.49	5.09	14.27	15.78
Q	15443—K	Do	8.77	8.32	.61	1:13.60	8.52	17.41	19.88
Q	15445—K	First pearling-cone meal	6.83	9.40	.60	1:15.60	4.09	16.80	16.10
Q	15446—K	Second pearling-cone meal	7.62	5.83	.17	1:34.30	1.62	16.45	9.56
		JAPAN:							
N	12614—L	First-break huller bran	9.63	7.32	1.27	1: 5.76	10.70	15.01	18.77
N	12615—L	Second-break huller bran	10.36	7.49	1.01	1: 7.41	7.90	15.27	17.57
V	11958—L	Mixture of first- and second-break huller brans	13.67	8.68	2.80	1: 3.10	9.83	13.50	14.49
		MIXTURES OF DIFFERENT TYPES:							
P	11981—K	First-break huller bran[4]	7.51	7.91	1.63	1: 4.80	8.62	14.05	14.95
S	12633—L	Do.[5]	11.99	8.02	2.47	1: 3.24	8.61	14.00	15.43
T	15454—K	Do.[6]	9.29	7.42	2.79	1: 2.66	8.50	13.91	9.70
P	11982—K	Second-break huller bran[4]	9.05	9.08	1.21	1: 7.50	6.87	13.82	14.79
S	12634—L	Do.[5]	11.05	6.84	3.37	1: 2.03	9.72	10.94	8.52
T	15455—K	Do.[6]	8.56	7.12	1.72	1: 4.14	5.90	13.87	9.76
Maximum			13.67	10.38	3.37		10.70	18.64	20.61
Minimum			6.83	4.63	.17		1.41	10.71	8.52
Average			9.45	8.02	1.29	1: 6.22	7.31	14.72	16.30

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[1] Mixture of red rice with Blue Rose rice.

[2] Direct from hullers; abnormal; omitted from summary.

[3] Samples were obtained from poor rice that was heavily milled and are abnormal.

[4] Mill was not operating.

[5] Mixture of Blue Rose and Honduras.

[6] Abnormal.

TABLE 4.—*Analyses of mixed brans as sold by the mill.*

Mill.	Sample No.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.	Protein (N×6.25).	Ether extract.
		Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per cent.*	*Per ct.*
A	[1] 25061—L	7.88	13.08	8.48	1:1.54	17.83	12.06	11.75
B	25073—L	10.46	10.54	4.66	1:2.26	12.26	14.06	15.73
C	25077—L	9.11	13.38	6.44	1:2.08	12.96	13.50	15.71
D	25099—L	8.85	8.33	3.52	1:2.37	10.64	14.13	14.77
E	25159—L	9.37	8.59	2.44	1:3.52	9.54	15.44	17.48
F	25166—L	7.78	11.81	4.77	1:2.48	11.45	13.88	13.51
G	25191—L	10.62	10.16	4.10	1:2.48	11.20	13.19	14.48
H	25199—L	10.02	10.06	3.30	1:3.04	11.01	13.78	14.63
I	11984—L	10.39	10.57	4.03	1:2.62	10.71	13.23	14.85
J	17077—L	8.70	9.83	3.84	1:2.56	10.95	13.60	15.55
K	15315—K	8.59	10.66	2.90	1:3.67	10.81	16.65	16.75
L	12659—L	10.72	11.15	5.39	1:2.07	10.58	12.41	12.84
M	12647—L	9.50	10.62	4.04	1:2.62	11.91	14.26	17.49
N	12618—L	9.84	8.64	3.33	1:2.59	12.19	13.26	15.37
O	[1] 12624—L	7.84	12.10	6.42	1:1.88	13.95	11.88	15.50
P	11983—K	9.66	9.64	3.33	1:2.80	10.40	13.39	13.89
Q	15444—K	7.85	8.72	2.24	1:3.90	9.61	16.53	16.03
R	[2] 12609—L	10.67	9.60	4.86	1:1.76	11.72	11.37	12.80
S	[1] 12638—L	9.80	10.50	6.70	1:1.57	15.10	10.94	10.10
S	[1] 12668—L	9.23	10.98	7.51	1:1.46	13.90	10.25	10.82
S	[1] 12669—L	8.27	12.08	7.59	1:1.59	18.51	11.05	13.46
S	[1] 12670—L	8.81	9.92	5.33	1:1.86	11.70	12.40	13.89
T	[3] 15456—K	10.59	7.31	4.04	1:1.81	9.37	12.34	5.97
T	[4] 15457—K	8.60	7.85	3.94	1:1.99	11.07	13.39	9.74
U	17093—L	10.45	8.40	4.19	1:2.00	10.54	12.86	13.08
V	11959—L	15.00	9.70	3.85	1:2.52	12.60	12.68	13.40
Maximum		15.00	13.38	6.44		12.96	16.65	17.49
Minimum		7.78	7.85	2.24		9.54	11.88	9.74
Average		9.65	10.03	3.78	1:3.77	11.28	13.79	14.75

[1] Omitted from summary, as ground hulls probably had been added to sample.
[2] Omitted from summary, as mill was milling abnormal, damaged rice.
[3] Omitted from summary, as mill was running on a mixed lot of broken rice.
[4] Sample was taken from a lot of bran ready for the market. Exact history of bran unknown.

TABLE 5.—*Analyses of rice polishes.*

Mill.	Sample No.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.	Protein (N×6.25).	Ether extract.
		Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per cent.*	*Per ct.*
A	25060—L	9.10	5.53	0.39	1:14.19	3.67	13.44	13.68
B	25075—L	11.04	6.02	.53	1:11.35	2.69	13.50	11.67
C	25084—L	10.10	6.44	.83	1: 7.75	2.25	12.25	10.15
C	[1] 25085—L	10.49	3.42	.41	1: 8.35	1.89	10.69	[2] 5.72
D	25097—L	9.44	4.56	.64	1: 7.13	2.20	12.69	9.10
E	25161—L	10.13	4.25	.32	1:13.29	1.76	12.63	9.13
F	[3] 25172—L	11.30	7.96	1.11	1: 7.17	2.45	14.19	10.73
F	[3] 25171—L	13.03	3.19	.43	1: 7.42	.94	12.13	[2] 4.24
G	25178—L	10.57	4.68	.24	1:19.51	1.38	11.06	8.59
I	11990—L	10.08	4.37	.30	1:14.56	.99	11.02	7.77
J	[4] 17078—L	9.88	3.07	.31	1: 9.90	.56	10.93	[2] 5.61
K	15316—K	5.64	2.07	.40	1: 5.17	2.29	9.31	12.02
L	12660—L	9.81	4.75	.30	1:15.83	.77	11.91	8.51
M	12651—L	9.29	5.46	.54	1:10.11	1.73	15.24	12.34
N	12617—L	8.56	4.44	.47	1: 9.44	2.27	12.55	12.10
O	12625—L	7.31	9.61	1.03	1: 9.33	2.52	13.52	17.75
P	11984—K	9.37	5.12			1.90	12.38	8.38
R	[5] 12608—L	9.65	2.43	.42	1: 5.78	1.74	7.87	6.39
S	12635—L	10.22	5.95	.96	1: 6.20	2.10	13.10	12.27
T	[6] 15458—K	7.50	4.42	1.40	1: 3.16	3.53	12.21	6.29
U	17089—L	8.70	6.40	1.17	1: 5.47	3.39	11.94	12.98
V	11962—L	6.68	5.81	1.28	1: 4.54	2.60	11.89	9.22
Maximum		13.03	9.61	1.40		3.67	15.24	13.68
Minimum		5.64	2.07	.24		.56	7.87	6.29
Average		9.45	4.97	.64	1: 7.76	2.07	12.11	9.75

[1] Polish from a second brush.
[2] The figures for ether extract in these samples are not representative and were not used in obtaining minimum percentage.
[3] These two polishes are mixed before being put upon the market.
[4] In this mill the rice is scoured by three pearling cones before it is sent to the brush.
[5] Low-grade rice that was heavily milled; polish abnormal.
[6] Remilling mixed lot of broken rice; polish abnormal.

TABLE 6.—*Analyses of miscellaneous samples of interest.*

Mill.	Sample No.	Description of sample.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.	Protein (N× 6.25).	Ether extract.
			Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
A....	25054—L	Light or blighted grains from monitor.	7.43	18.60	16.80	1: 1.10	35.70	5.80	2.80
A....	25058—L	Blighted grains mixed with stone-reel bran.	8.60	16.20	13.10	1: 1.24	26.70	8.90	6.60
A....	25055—L	Rice, Blue Rose type, from clean side of paddy machine.	13.80	1.10	.04	1:27.50	0.96	8.60	2.00
C....	25079—L	Dust from dust collector connected with hull grinder.	8.40	29.90	25.50	1: 1.17	12.60	7.80	3.80
F....	25176—L	Brown rice from package as found on the market.	10.30	1.30	.08	1:16.25	.80	7.80	1.90
I.....	11989—L	Polish taken from brush machine by air blast.	9.49	7.28	.55	1:13.23	2.10	11.75	12.38
J.....	17060—L	Light or blighted grains from monitor.	10.21	17.40	15.90	1: 1.09	32.97	4.81	1.25
K....	15310—K	.....Do....................	9.28	16.40	14.47	1: 1.13	29.90	6.72	1.48
P....	11979—K	Ground and bolted rice hulls from mill.	7.98	19.84	18.69	1: 1.06	36.72	3.56	.93
P....	13449—K	Bran standardized with ground hull.[1]	10.89	10.43	6.04	1: 1.70	12.80	11.28	8.91
P....	13452—K	.....Do.[1]	10.34	11.64	6.51	1: 1.70	16.03	11.64	10.38
Q....	15438—K	Ground and bolted rice hulls from mill.	5.55	18.91	17.62	1: 1.07	36.01	3.76	1.10
Q....	15433—K	Light or blighted grains from monitor.	9.26	13.12	11.54	1: 1.10	27.03	7.96	1.55
Q....	15436—K	Dust from dust collector connected with hull grinder.	6.40	27.71	24.89	1: 1.10	17.08	7.00	2.99
G....	25183—L	Rice, Honduras type, from clean side of paddy machine.	14.80	1.20	.20	1: 6.00	.96	8.90	2.20
S.....	12636—L	Polish taken from brush machine by air blast.	9.80	6.68	1.38	1: 4.77	2.04	13.16	13.15
U....	17090—L	.....Do....................	8.49	8.35	.88	1: 9.48	3.65	13.69	18.99

[1] Shipped unlabeled as 20 per cent fat + protein.

MILLING AND CHEMICAL RESULTS ON CONTROL SAMPLES FROM A TYPICAL MILL.

The second part of the work consisted in the collection and analysis of the several reduction products obtained under carefully controlled and known conditions. A typical rice mill of moderate size was selected and through the courtesy of the owners representatives of the department were given control of its operation. Arrangements were made to spout the various bran streams separately and to collect and weigh each portion of a given run as it was taken off. Samples were drawn from each stream and were analyzed separately. A complete feed analysis was made of the by-product samples and a moisture determination of the rice at various stages of milling. Four lots of rice were milled in this manner.

Lot A consisted of No. 1 Blue Rose type rice. This lot contained little or no red rice and was of as good grade as is ever used for milling. It cupped 42 pounds to the bushel. The regular adjustment of the stones and hullers was used in milling this rice.

The milling results on this lot are given in Table 7.

TABLE 7.—*Yield of by-products and cleaned rice obtained from the milling of 13,935 pounds of No. 1 Blue Rose type rice. Lot A.*

[Quantity of rice milled: 71 bags or 86 barrels of 162 pounds each; total weight, 13,935 pounds].

Cleaned rice and by-products.	Yield.		Cleaned rice and by-products.	Yield.	
	Pounds.	*Per cent.*		*Pounds.*	*Per cent.*
Hulls	2,706.0	19.4	Polish	397.0	2.9
Brans:			Head rice	7,900.0	56.6
Stone reel (25.2 per cent)	294.5	2.1	Second-grade rice	1,130.0	8.1
First break (33.6 per cent)	391.5	2.8	Brewer's rice	270.0	1.9
			Chicken feed	100.0	0.7
Second break (41.2 per cent)	481.0	3.4	Waste	265.0	1.9

The laboratory results on the samples from this run are shown in Table 8.

TABLE 8.—*Chemical composition of by-products and of rice at different stages of milling No. 1 Blue Rose type rice. Lot A.*

Sample No.	Description of sample.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.
		Per cent.	*Per cent.*	*Per cent.*		*Per cent.*
11996—L	Hulls	7.51	17.90	17.59	1:1.02	43.19
11993—L	Stone-reel bran	8.91	13.46	9.62	1:1.40	23.54
12675—L	First-break bran	9.28	7.43	1.03	1:7.21	9.13
12677—L	Second-break bran	9.91	7.24	1.19	1:6.08	7.83
	Calculated analysis of mixed bran	9.45	8.87	3.26	1:2.71	12.23
12679—L	Rice polish	8.87	7.39	.60	1:12.32	1.59
11991—L	Rough rice before milling	11.95				
11992—L	Cleaned rough rice	11.67				
11995—L	Hulls and bran after the monitor	8.84				
11997—L	Rice after stone monitor going to paddy	12.68				
11999—L	Rice from rough side of paddy machine	11.90				
11998—L	Rice from clean side of paddy machine	12.33				
12000—L	Rice after first-break huller screen	12.55				
12678—L	Rice after brush machine	12.30				
12678—L	Rice after brush machine (finely ground)	11.07	0.30	0.01	1:30.0	0.37

Sample No.	Description of sample.	Protein (N ×6.25).	Ether extract.	Nitrogen-free extract.	Pentosans.	Starch.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
11996—L	Hulls	1.93	0.59	28.88	16.73	1.25
11993—L	Stone-reel bran	9.68	8.61	35.80	12.95	7.82
12675—L	First-break bran	14.93	20.11	39.12	7.35	12.63
12677—L	Second-break bran	14.60	18.68	41.74	7.39	16.37
	Calculated analysis of mixed bran	13.47	16.62	39.36		
12679—L	Rice polish	12.79	16.99	52.37	4.68	33.88
11991—L	Rough rice before milling					
11992—L	Cleaned rough rice					
11995—L	Hulls and bran after the monitor					
11997—L	Rice after stone monitor going to paddy					
11999—L	Rice from rough side of paddy machine					
11998—L	Rice from clean side of paddy machine					
12000—L	Rice after first-break huller screen					
12678—L	Rice after brush machine					
12678—L	Rice after brush machine (finely ground)	7.87	0.52	79.87		

Lot B consisted of No. 3 Blue Rose type rice. This lot contained considerable red rice and some cracked and over-ripe grains, and was of very ordinary quality. It cupped 43 pounds to the bushel. The stones were lowered to the usual height, the hullers set loose, and fed at regular speed. The rice was brushed with large feed on brush. The whole process was regulated throughout to preserve the grain rather than to obtain a highly milled rice.

The milling results on this lot are given in Table 9.

TABLE 9.—*Yield of by-products and cleaned rice obtained from the milling of 36,080 pounds of No. 3 Blue Rose type rice. Lot B.*

[Quantity of rice milled: 183 bags or 222.7 barrels of 162 pounds each; total weight, 36,080 pounds.]

Cleaned rice and by-products.	Yield.		Cleaned rice and by-products.	Yield.	
	Pounds.	*Per cent.*		*Pounds.*	*Per cent.*
Hulls	6,872	19.0	Polish	1,179	3.2
Brans:			Head rice	22,000	60.9
Stone reel (29.3 per cent)	755	2.1	Brewer's rice	2,880	8.0
First break (30.4 per cent)	727	2.0	Chicken feed	150	0.4
Second break (40.3 per cent)	1,001	2.7	Waste	516	1.4

The laboratory results on the samples from this run are shown in Table 10.

TABLE 10.—*Chemical composition of by-products and of rice at different stages of milling No. 3 Blue Rose type rice. Lot B.*

Sample No.	Description of sample.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.	Protein (N× 6.25).	Ether extract.	Nitrogen-free extract.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
18066—L	Rice hulls	5.87	20.01	19.76	1:1.01	38.72	2.08	0.47	32.85
18063—L	Stone-reel bran	7.52	15.28	12.52	1:1.22	20.35	9.47	8.02	39.36
18071—L	First-break bran	7.30	7.71	1.42	1:5.43	9.03	14.93	20.20	40.83
18073—L	Second-break bran	7.25	7.77	1.34	1:5.80	7.72	14.68	19.51	43.07
	Calculated analysis of mixed bran	7.35	10.04	4.76	1:2.32	11.94	13.17	16.22	41.29
18075—L	Rice polish	6.38	8.01	0.91	1:8.80	4.45	13.48	19.04	48.64
18061—L	Rough rice before milling	10.42							
18062—L	Cleaned rough rice	10.91							
18064—L	Rice, bran, and hulls after stone	10.77							
18065—L	Hulls and bran from stone monitor	7.55							
18067—L	Rice from monitor going to paddy	10.93							
18069—L	Rice from rough side of paddy machine	10.57							
18068—L	Rice from clean side of paddy machine	11.13							
18078—L	Rice after first-break reel	11.90							
18072—L	Rice after second-break huller reel	10.33							
18074—L	Rice after brush machine	11.32							
18074—L	Rice after brush machine (finely ground)	10.51	0.46	0.03	1:15.3	0.56	8.03	0.64	79.80

Lot C consisted of No. 4 Japan-type rice. This lot contained considerable red rice and was light and chaffy on account of immature grains. It cupped 40 pounds to the bushel. In milling this rice the stones were set lower and the hullers set very loose.

The milling results on this lot are given in Table 11.

TABLE 11.—*Yield of by-products and cleaned rice obtained from the milling of 24,380 pounds of No. 4 Japan-type rice. Lot C.*

[Quantity of rice milled: 129 bags or 150.49 barrels of 162 pounds each; total weight, 24,380 pounds.]

Cleaned rice and by-products.	Yield.		Cleaned rice and by-products.	Yield.	
	Pounds.	*Per cent.*		*Pounds.*	*Per cent.*
Hulls	4,560	18.7	Polish	868	3.5
Brans:			Head rice	15,500	63.5
Stone reel (21.0 per cent)	406	1.6	Brewer's rice	1,440	5.9
First break (41.8 per cent)	806	3.3	Waste	83	0.3
Second break (37.2 per cent)	717	2.9			

The laboratory results on the samples from this run are shown in Table 12.

TABLE 12.—*Chemical composition of by-products and of rice at different stages of milling No. 4 Japan-type rice. Lot C.*

Sample No.	Description of sample.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.	Protein (N×6.25).	Ether extract.	Nitrogen-free extract.
		Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
12886–L	Rice hulls	6.19	18.46	17.85	1: 1.04	39.98	2.49	1.08	31.80
12683–L	Stone-reel bran	10.28	13.89	9.90	1: 1.40	18.09	9.89	9.87	37.98
12691–L	First-break bran	9.56	9.26	3.82	1: 2.42	10.82	12.56	14.54	43.26
12693–L	Second-break bran	9.25	7.02	1.02	1: 6.88	7.17	13.62	16.53	46.41
	Calculated analysis of mixed bran	9.60	9.40	4.06	1: 2.35	10.99	12.39	14.30	43.32
12695–L	Rice polish	8.17	5.93	0.43	1:13.79	2.18	11.67	12.22	59.83
12680–L	Rough rice before milling	11.99							
12684–L	Rice hulls and bran after stones	12.14							
12685–L	Hulls and bran from stone monitor	9.26							
12687–L	Rice from stone monitor	12.14							
12689–L	Rice from rough side of paddy machine	11.51							
12690–L	Rice after first-break huller reel	12.50							
12692–L	Rice after second-break huller reel	12.47							
12694–L	Rice after brush machine	12.38							
12694–L	Rice after brush machine (finely ground)	10.57	0.38	.09	1: 4.22	0.47	7.00	0.59	80.89

Lot D consisted of No. 1 Honduras-type rice. This lot was slightly seedy and weather damaged. It cupped 41 pounds per bushel. In milling, the stones were raised on account of the long grain, and the hullers were set very loose, as in milling rice of the Japan type, and were fed slower.

The milling results on this lot are given in Table 13.

TABLE 13.—*Yield of by-products and cleaned rice obtained from the milling of 35,970 pounds of No. 1 Honduras-type rice. Lot D.*

[Quantity of rice milled: 186 bags or 222 barrels of 162 pounds each; total weight, 35,970 pounds.]

Cleaned rice and by-products.	Yield.		Cleaned rice and by-products.	Yield.	
	Pounds.	*Per cent.*		*Pounds.*	*Per cent.*
Hulls	7,532	20.9	Head rice	15,000	41.7
Brans:			Second-grade rice	5,000	13.9
Stone reel (29.1 per cent)	878	2.4	Third-grade rice	2,100	5.8
First break (34.3 per cent)	1,033	2.8	Brewer's rice	960	2.6
Second break (36.6 per cent)	1,101	3.1	Chicken feed	400	1.1
Polish	1,225	3.4	Waste	741	2.1

The laboratory results on the samples from this run are shown in Table 14.

TABLE 14.—*Chemical composition of by-products and of rice at different stages of milling No. 1 Honduras-type rice. Lot D.*

Sample No.	Description of sample.	Moisture.	Ash.	Ash insoluble in 10 per cent HCl.	Ratio of insoluble ash to total ash.	Crude fiber.	Protein (N× 6.25).	Ether extract.	Nitrogen-free extract.
		P. ct.	*P. ct.*	*P. ct.*		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
18051-L	Rice hulls	8.50	20.33	19.29	1: 1.05	37.24	2.09	0.50	31.34
12698-L	Stone-reel bran	9.63	15.75	12.80	1: 1.23	22.14	9.36	6.51	36.61
18056-L	First-break bran	9.77	7.26	.74	1: 9.81	7.60	15.99	18.38	41.00
18058-L	Second-break bran	9.55	6.94	.77	1: 9.01	5.92	14.93	15.75	46.91
	Calculated analysis of mixed bran	9.65	9.62	4.27	1: 2.24	11.22	13.67	13.96	41.88
18060-L	Rice polish	7.93	7.05	.52	1:13.56	2.19	13.45	13.48	55.90
18052-L	Rough rice before milling	12.24	....	....	....	....	....	....	....
12697-L	Cleaned rough rice	11.75	....	....	....	....	....	....	....
12699-L	Rice, bran, and hulls after stone	11.57	....	....	....	....	....	....	....
12700-L	Hulls and bran from stone	7.73	....	....	....	....	....	....	....
12696-L	Rice from monitor going to paddy	11.74	....	....	....	....	....	....	....
18053-L	Rice from clean side of paddy machine	12.08	....	....	....	....	....	....	....
18054-L	Rice from rough side of paddy machine	11.75	....	....	....	....	....	....	....
18055-L	Rice after first-break hullers	12.60	....	....	....	....	....	....	....
18057-L	Rice after second-break hullers	12.70	....	....	....	....	....	....	....
18059-L	Rice after brush machine	12.43	....	....	....	....	....	....	....
18059-L	Rice after brush machine (finely ground)	11.41	.33	.03	1:11.00	.59	9.71	.54	77.42

INTERPRETATION OF RESULTS.

CONTROL PRODUCTS.

A few interesting comparisons may be made from the milling results. The percentage of hulls from a given lot of rice varied from 18.7 per cent to 20.9 per cent, the lowest figure being for lot C of Japan-type rice and the highest figure for lot D, Honduras type. The yield of useful rice by-products—that is, all the brans and the polish—varied from 10 per cent for lot B to 11.7 per cent for lot D. As lot B was very lightly milled, this variation would be expected.

The yield of finished rice of all grades varied from 64 per cent for lot D to 68.9 per cent for lot B, showing, as would be expected, that a high yield of rice corresponds to a low yield of by-products. The percentage of the bran coat taken off at the four stages varied greatly. It would seem that more satisfactory milling results might be obtained if it were possible to make the reduction at each stage more nearly uniform.

The chemical results given in Tables 8, 10, 12, and 14 show many interesting features. The moisture of the rough rice is seen to be mainly in the kernel, as the moisture of the hull in all cases was markedly less than that of the other samples. A lower moisture content was found in the several by-products than in the rice itself. This may be due in part to the interior of the kernel having a higher moisture content than the exterior portions, but probably is due mainly to the drying of the by-products by the heat developed in the milling process. This theory is supported by the fact that the polish is of lower moisture content than are the brans.

The ash in the stone-reel bran from the four lots of rice milled approximated 15 per cent, showing the presence of hulls in this bran. This also is shown markedly by the ash insoluble in hydrochloric acid, which averaged about 11 per cent, as compared with about 1 per cent for the huller brans and polish. Lot C, composed of Japan-type rice, was the only lot that showed a high insoluble ash in the first-break huller bran. This is accounted for probably by the fact that the small grains of rice of the Japan type do not separate so well in the paddy machine as do other types of rice.

A marked tendency for the ether extract to exceed protein was observed in all brans, particularly in those from Blue Rose rice, which, in general, are higher in ether extract than, and have approximately the same amount of protein as, brans from the other types of rice. The relation of ether extract to protein gives some indication as to the addition of hulls, since hulls contain considerably more protein than ether extract, and their addition to the bran tends to bring the determinations for these two constituents more closely together than would be the case if the bran were free from hulls. This has been observed in the case of so-called 20 per cent brans, which have been standardized to 20 per cent fat plus protein by the addition of hulls. The trade custom of rating rice bran on the basis of the fat plus protein content is of long standing.

The percentage of crude fiber decreased markedly as the reduction process was continued. The high figures for stone-reel bran are, of course, due to the presence of hulls. The determinations of pentosans and starch made on samples of lot A appear to furnish no information regarding the products not given by the other figures.

In the calculated analyses given in Tables 8, 10, 12, and 14, for the mixed brans as they would ordinarily appear on the market, the ash in all cases was 10 per cent or less, the insoluble ash in all cases was below 5 per cent, and the fat plus protein ranged from 26.7 per cent to nearly 30 per cent. The crude fiber was always above 10 per cent, a figure considered by many chemists to be the limit for a pure rice bran. The nitrogen-free extract approximated 40 per cent. This figure, however, seems to be of little use in determining the character of the product, except that in some cases a high figure may confirm the presence of a large amount of broken rice.

The results show that rice polish is characterized by very low acid-insoluble ash, by low crude-fiber value, and by high nitrogen-free extract. It should have a fat plus protein content above 20 per cent. The rice polish in lot D was somewhat abnormal for the reason that, on account of the light milling to which the rice had been subjected, the portion taken off in the brush machine consisted in part of the material which usually would be taken off in the second-break hullers.

ALL SAMPLES.

A consideration of the chemical results on all samples taken shows that all the rice hulls examined were very high in both ash and fiber and were of such low protein and fat content as to have practically no feeding value. In addition, their physical structure renders them harmful to animals if fed in too large amounts.

The stone-reel bran was uniformly much higher in total ash, acid-insoluble ash, and crude fiber, and was lower in protein and fat than were the huller brans. This was due to the presence of the hulls which entered the stone-reel bran after they had been broken up by the stones. The analysis of this by-product would indicate that usually it contains from 25 to 50 per cent of hulls. The huller brans were nearly all very low in fiber and acid-insoluble ash, showing their comparative freedom from hulls, and were high in protein and fat. Their composition would make them a very rich feeding stuff if used alone. At present, however, huller brans are not used for feeding purposes, partly for the reason that they do not keep well and partly because millers always have made a practice of including the product of the stone reel in their bran. This mixture is the bran as commonly found on the market and contains an amount of hulls from the stone-reel bran which would seem to add materially to the keeping qualities of the product, and at the same time to give a feed acceptable to the consumer. This product, when produced under known conditions that preclude the addition of ground hulls, should contain over 26 per cent fat plus protein. It should not exceed 13 per cent of crude fiber or 5 per cent of ash insoluble in hydrochloric acid.

All the chemical determinations given in the tables are of value in judging the nature of by-products of rice found on the market. The presence of rice hulls in rice bran is indicated at once by high ash, particularly insoluble ash, and by a low ratio of insoluble to total ash. Rice hulls also are indicated by a high crude-fiber content. Low figures in protein and fat may be due to an excess of hulls or to an excess of broken rice due to poor material or careless milling, but, when they are considered in connection with the figures for ash and fiber, the character of the product can be judged accurately.

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